REMARKS

Claims 1 through 19 were presented at filing and by Office Action mailed Claim 1-4, 7-19 stand rejected under 35 u.s.c 103(a) as unpatentable over Mansfield of record. The Examiner admitted a lack, in Mansfield, of "complete cylindrical geometry" of the coil pair. However, the Examiner should note a compelling reason for the inapplicable nature of the Mansfield reference. The present invention is directed to shielded gradient coils comprising an extended Maxwell pair with a single shield. Mansfield describes his Maxwell pair embodiment at col. 8, line 60 - col. 9 line 7; col. 17, line 25 - col. 18 line 40. For each of these references Mansfield unequivocally teaches two (or more) screens, forming two shield means, as in Mansfield figures 23 & 25, which show a shield S_2, at a first radius and a shield S_1 at a greater radius. The present invention comprises a (single) shield at one radius.

Applicant concedes that a casual perusal of the claims as filed includes recitation of a "pair" of cylindrical shield coils. The text and figure are clear that this "pair" reflects the nomenclature Maxwell "pair". The single shield of the present invention comprises a cylindrical structure for each current loop of the Maxwell pair, e.g. a shield pair at a common radius. Claim 2 recites "each of said shield coils being of radius b", emphasis added. Applicant offers amendment to the claims language to remove any ambiguity. Moreover, applicant takes this opportunity to include the limitation of claim 2 into claim 1 inasmuch as the unit of invention is the cooperative activity of both the active shield and the shielded gradient coils.

The Examiner has specifically cited Mansfield, of record, col. 17, line 30-34 and figure 25. In view of the single active screen of the present invention it is clear that the reference, requiring two active cylindrical screens is distinguished. In view of the present amendment of claim 1 to include the limitation of claim 2, applicant submits that claim 1, as amended, is patentably distinct from the reference and should be allowed. Claims 3, 5, 7-9 inclusive should thus be allowed as depending from an allowable claim

The method claim 11 has been redrafted as new claim 20. It is useful to comment here on the substance of the claim and the antecedent in the specification.

The conventional manner of expressing a field distribution (such as a magnetic dipole field) is a spherical (or cylindrical) harmonic expansion. So expressed, the conventional approach to design of component for generating a desired magnetic field is to consider B (r, θ, φ)

at a field point as a function of a current increment at a source point, with careful attention to geometry and current direction. The relationship may be expressed in differential or integral form and the field properties and obtained to a sufficient accuracy by exploiting symmetries so as to remove terms from the mathematical expansions. The present invention uses "target field" techniques to design an actively shielded linear gradient. The target field approach is a mathematical inversion of the field – current relationship. That is the field is <u>specified</u> and the current is computed for the inverse relationship. The target field technique is known and acknowledged (page 3, line 8-14). The present invention is based upon a target field technique to actively shield an <u>extended</u> Maxwell pair gradient coil structure with a <u>single</u> screen. The gradient B_z is selected to be linear within a cylindrical region of length z_o and radius a and with a coaxial cylindrical region of radius b > a enclosing the axial extension z_o.

Some minor changes in the specification are made to correct typographical errors. In particular, the equation at p 4, line 27 shows an exponent "5" which should be corrected to "4". Antecedent basis for the correction may be found at page 5, line 5, which follows from equation 3 and 1.

Applicant has amended the claims to more clearly and distinctly claim the invention. It is believed that all claim are in condition for allowance, which action is respectfully solicited.

Attached hereto is a marked-up version of the changes made to the specification and claims by the current amendment. The attached page is captioned "**<u>Version With Markings To Show Changes Made</u>**."

Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECIFICATION

Paragraph beginning at page 4, line 27 to page 5, line 2 has been amended as follows:

To improve the linearity of the gradient near the origin O, the first non-linear term is set equal to zero, or $c_3=0$. This leads to the following linearity-establishing condition:

$$\int_0^{kmax} dkk[^5]\ \underline{^4} I_{\varphi}^{p}(k) S_0(k) K_0'(ka) I_0(k\rho)=0 \qquad (3)$$

where ρ is the radial distance from the z-axis, K is the Bessel function of the second kind, k_{max} is a suitable upper limit of the integration, and $S_0(k)$ may be referred to as the shielding factor, given by

$$S_0(k)=1-K_1(kb)I_1(ka)/K_1(ka)I_1(kb). \qquad (4)$$

The linearity-establishing condition (3) given above should ideally hold for all values of ρ. For practical applications in NMR, however, ρ may be set equal to the maximum value of a region occupied by the sample. For an NMR tube of radius 5mm, for example, ρ may be set equal to 2.5mm.

IN THE CLAIMS

Claim 1 has been amended as follows:

1.(amended) An extended Maxwell pair comprising:

a pair of cylindrical gradient coils disposed coaxially around and along a z-axis extending in z-direction and symmetrically with respect to an origin, each being of radius a and of axial length d, said pair being mutually separated by a center-to-center distance z_0 which is greater than d; and

means for causing [same] equal magnitude currents to flow through said gradient coils in mutually opposite directions;

values of d and z_0 being selected such that said equal currents generate a magnetic field along said z-axis with a linear gradient near said origin in said z-direction.

a pair of cylindrical shield coils disposed coaxially around said gradient coils, each of said shield coils being of radius b which is greater than a, said means causing said equal

magnitude currents to flow through said shield coils, said shield coils serving to cancel magnetic field outside said shield coils.

Claim 2 has been cancelled.

Claim 4 has been cancelled.

Claim 6 has been cancelled.

Claim 7 has been amended as follows:

7.(amended) The extended Maxwell pair of claim [6] 5 wherein each of said shield coils comprises a wire which is wound cylindrically at specified intervals, said intervals being determined such that said shield coils have effects of canceling magnetic field [outside] external to said shield coils.

Claim 9 has been amended as follows:

9.(amended) The extended Maxwell pair of claim [2] 1 wherein a, b, d and z_0 satisfy an equation given by $\int_0^{kmax} dk k^4 \{\sin(kd/2)\sin(kz_0/2)/(kd/2)\} S_0(k) K_0'(ka) I_0(k_\rho)=0$ where $S_0(k)=1-K_1(kb)I_1(ka)/K_1(ka)I_1(kb)$, I_1 and K_1 are modified Bessel functions, k_{max} is an appropriately selected upper limit of integration and ρ is an appropriately selected value less than a.

Claim 11 has been amended as follows:

11.(amended) A method of designing an extended Maxwell pair, said extended Maxwell pair comprising:

a pair of cylindrical gradient [coils] coil surfaces disposed coaxially around and along a z-axis extending in z-direction and symmetrically with respect to an origin, each of said shield coil surfaces being of radius a and of axial length d, said pair being mutually separated by a center-to-center distance z_0 which is greater than d; and

a pair of cylindrical shield [coils] coil surfaces disposed coaxially around said primary coils, each of said shield [coils] coil surfaces being of radius b which is greater than a;

said method comprising the steps of:

specifying a gradient coil current distribution related to said gradient coils as equal currents are caused to flow through said gradient coils;

obtaining a shield coil current distribution related to said shield coils as said equal currents are also caused to flow through said shield coils such that magnetic field outside said shield coils is cancelled;

[calculating] expanding resultant magnetic field near said origin due to said equal currents by Fourier-Bessel [expansion method] series;

deriving from said calculated resultant magnetic field a linearity-establishing equation for obtaining a linear gradient around said origin; and

selecting a value of one of the parameters selected from the group consisting of d and z_0 to solve said linearity-establishing equation for the other of said parameters.

Claim 12 has been amended as follows:

12.(amended) The method of claim 11 further comprising the step of [designing] approximating said shield [coils] coil current distribution [according to said derived shield coil current distribution] by discrete conductor disposition on said cylindrical shield coil surfaces.

New claim 20 has been added.